LMI
GOVERNMENT CONSULTING
THE OPPORTUNITY TO MAKE A DIFFERENCE HAS NEVER BEEN GREATER

Economics of Converting Military Waste to Fuel

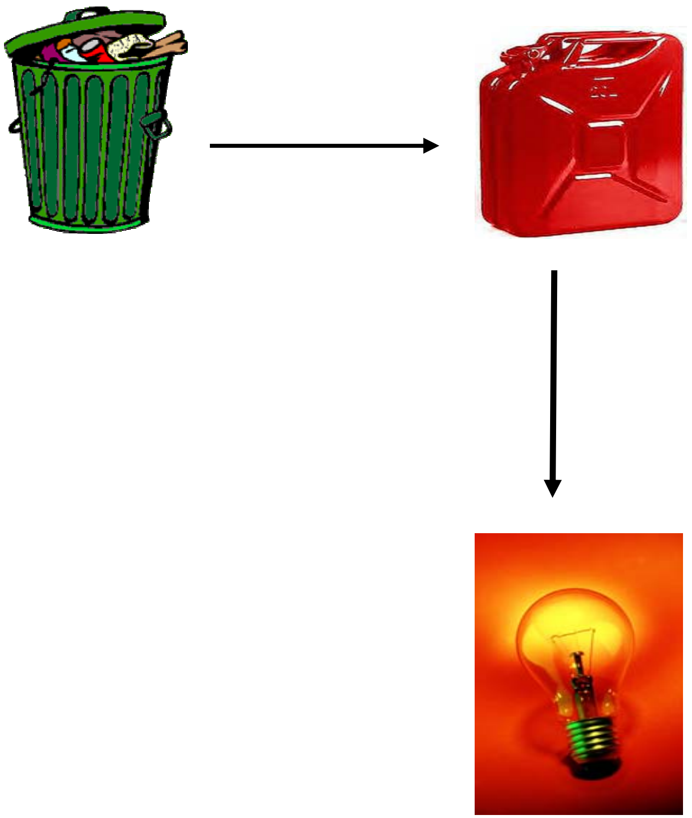
Dr. Michael E. Canes

IAEE North American Meetings; Denver, Colorado

September 20, 2005

Conversion of Military Waste to Fuel

- Paradigm shift:
  - Treat waste as a resource
  - Transform into fuel, fuel into power
  - Logistics savings
  - Smaller footprint
- But:
  - Will it work?
  - What are its economics?

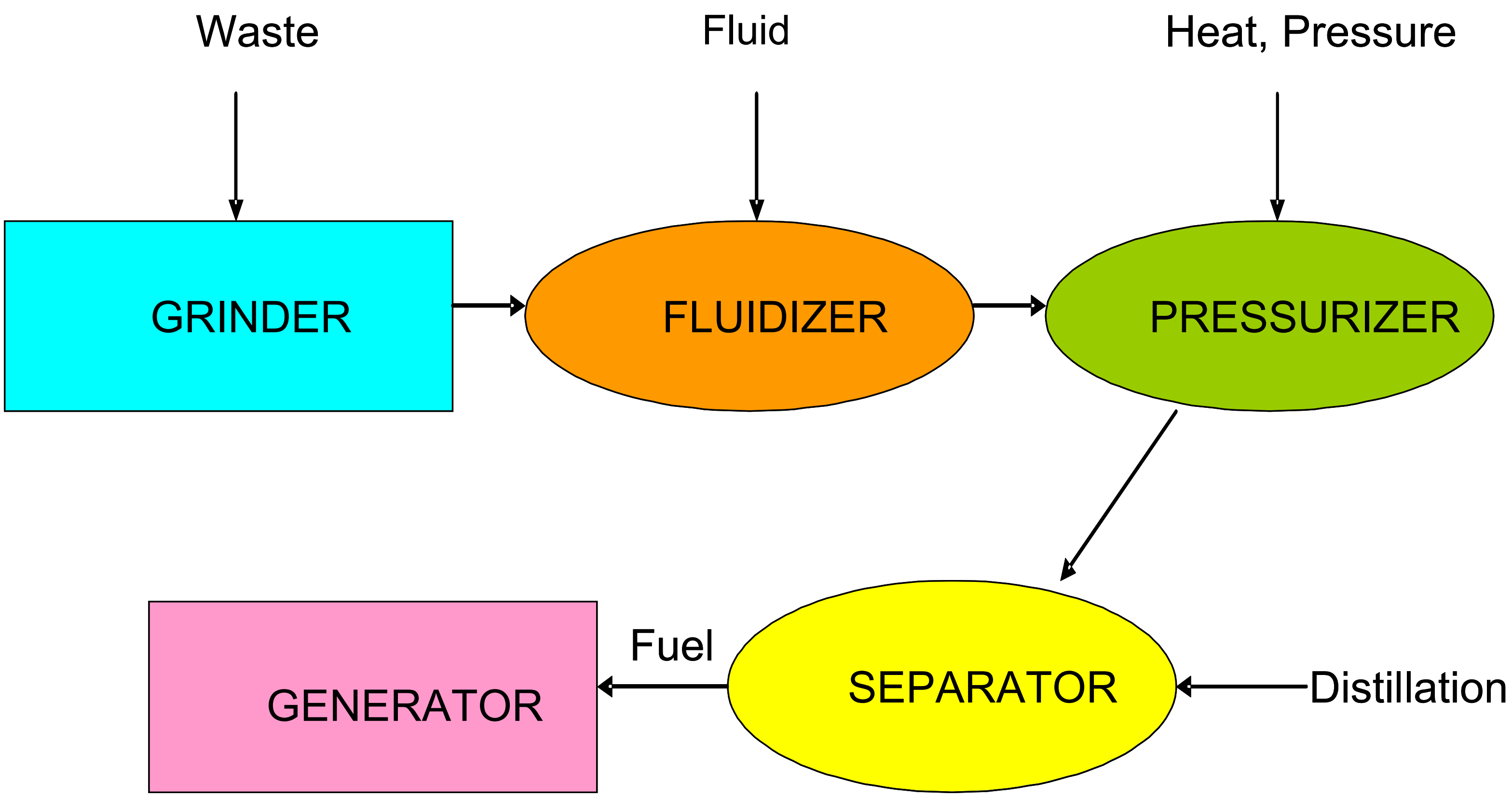


Waste to Fuel Technologies

- Many alternatives:
  - Pyrolysis
  - Air gasification
  - Supercritical fluid gasification
  - Aqueous-phase reforming
  - Liquid anode fuel cell
  - Biodegradation

- Outputs
  - Hydrogen, methane, propane, gasoline, distillates including JP-8

Waste to Fuel Process Using Fluid, Heat & Pressure



Defense Advanced Research Projects Agency (DARPA) Supporting 3 Approaches

- DARPA's approaches:
  - Supercritical water depolymerization
  - Liquid anode fuel cell
  - Enzymatic biodegradation
- Project labeled "MISER"

(Mobile Integrated Sustainable Energy Recovery)

Assessment of MISER Net Benefits

- Assume MISER unit transforms military waste into sufficient liquid fuel to fire a 5kW generator
- Estimate resource savings
- Estimate capital & O&M costs
- Calculate Net Present Value
  - Re-estimate under varying assumptions

MISER Benefits

- Avoided cost of waste disposal
- Avoided cost of waste transport
- Avoided cost of transport fuel
- Avoided personnel cost
- Value of fuel produced

Avoided Cost of Waste Disposal

- = T*p*D

  Where: T = total tons of waste

  p = proportion processed by MISER

  D = per ton disposal cost

- 258 lbs of mixed waste/day needed to fuel a 5 kW generator
  - (MISER assumed 70% efficient; 18.8 lbs mixed waste/gallon of fuel, 5 kW generator burns 13.7 gal/day)
- Estimated average disposal cost = $100/ton*
- Then avoided waste disposal cost for 5 kW generator = **$13/day**

***Source: Hughes Associates**

Avoided Cost of Waste Transport

- = T*p*1/A*2M*Q

where: A = number of tons of waste per truck

M = miles traveled to waste site

Q = per mile truck depreciation rate

- Assume 5-ton truck, MISER at front lines (2.8 tons/truck, 186 miles each way, $1.88/mile)
- Then avoided waste transport cost = **$32/day**
- (Allocates 100% cost of trip to waste disposal)

Avoided Cost of Fuel to Transport Waste

- = T*p*1/A*2M*1/G*V(o)

  where: G = miles per gallon

  V(o) = cost of fuel at base camp

- Assume 5-ton truck fueled at base of operations

  (G = 4.1 mpg, V(o) = $13/gal*)

- Avoided transport fuel cost = **$54/day**

*Source: Defense Science Board, “More Capable Warfighting Through Reduced Fuel Burden”

Avoided cost of personnel

- = N*H*h

  where: N = Number of soldiers to dispose of waste

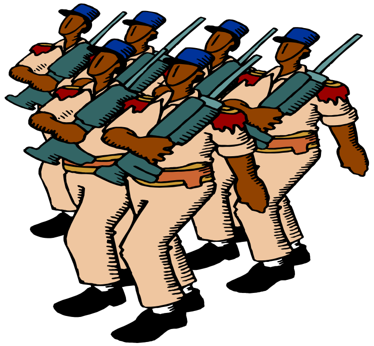
  (# of soldiers per truck × number of trucks)

  H = Hours of time/soldier

  h = hourly soldier compensation rate

- Assume 2 soldiers per truck, 30 mph truck speed, 1 hour to pick up & dispose of waste, $18.40/hour compensation rate

- Avoided personnel cost = **$23/day**



Fuel Value

- = 13.7*V(M)

  where: V(M) = cost/gal to deliver fuel M miles from base of operations

  V(M) = V(o) + c*M

  where: c = per gallon per mile cost of delivering fuel in a combat theater

- Assume tactical truck delivery ($.031/mile/gallon)
- Value of fuel at front lines = **$255/day**

Total Daily Estimated Savings from 5 kW-supporting MISER unit

Waste disposal	$13/day
Waste transport	$32/day
Transport fuel	$54/day
Personnel	$23/day
Fuel Value	$255/day
Total resource savings	**$377/day**

Capital Cost of MISER

- Estimated capital cost of 5 kW-supporting MISER unit using pyrolysis process:
  - @ 10 units produced = $28K
  - @10,000 units produced = $18.7K
- Scale factor for other unit sizes:

$$X = Y_i \times (S/5)^n \qquad i = 1,2$$

Where: X = estimated cost of MISER of size X

S = MISER unit size (10kW, 15kW, etc.)

n = engineering scale factor (.6-.8)

Y_1= cost of 5kW MISER when 10 are produced

Y_2= cost of 5kW MISER when 10,000 are produced

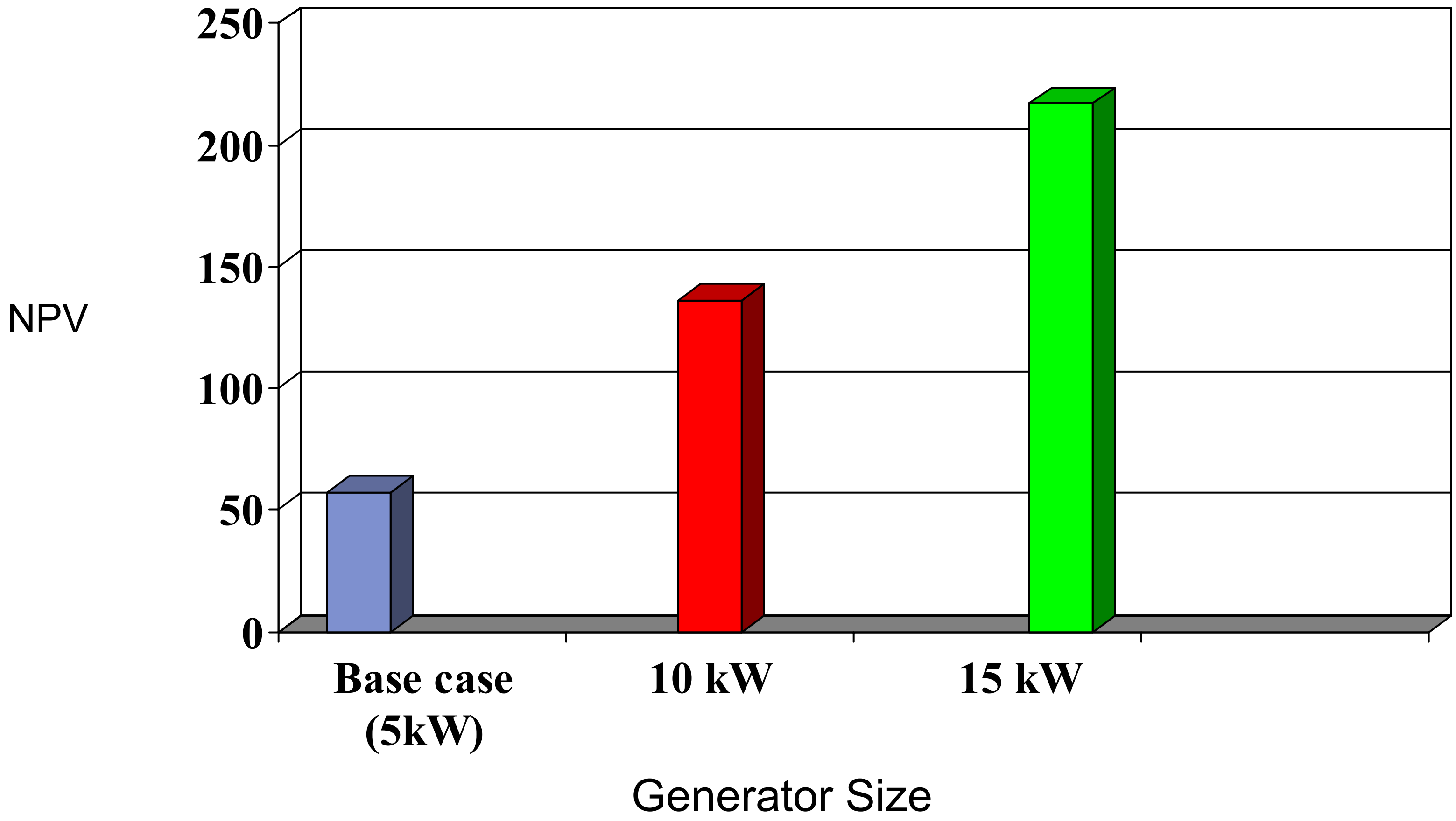
Key Base Case Assumptions (theater of operations)

- Annual O&M costs are 10% of capital costs
- 15 year equipment lifetime
- 5% discount rate
- MISER operates 8 hours/day, 90 days/year
- Fuel value = $13/gallon at base of operations

5kW MISER Net Present Value (NPV) Under Alternative Assumptions (in theater)

Assumption	NPV ($K)
1) Base case	57
2) 6% discount rate	52
3) 10 year lifetime	36
4) Fuel value only (no waste disposal savings)	21
5) Fuel $2.50/gal at base	15
6) Capital costs $50K	15
7) Combination of 3,6	(1)

Effect of Generator Scale on MISER NPV



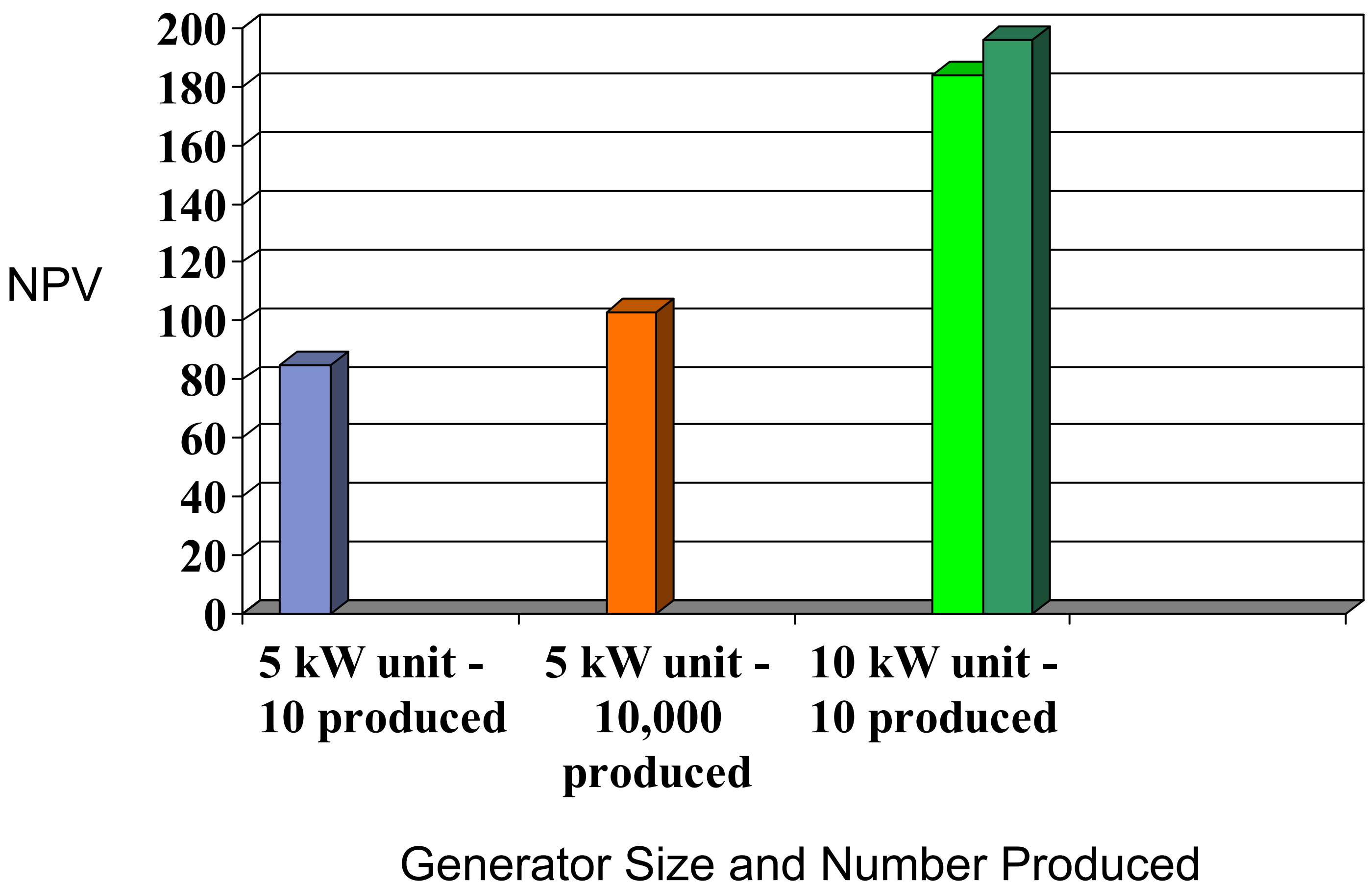
Key Base Case Assumptions (domestic installation)

- MISER operates 20 hours/day, 360 days/year
- Fuel value = $2.50/gallon
- 15 year equipment lifetime
- 5% discount rate
- Annual O&M costs 10% of capital costs

5kW MISER Net Present Value Under Alternative Assumptions (domestic)

Assumption	NPV ($K)
1) Base case	85
2) 6% discount rate	77
3) 10 year lifetime	72
4) Fuel $1.50/gal at base	45
5) Capital cost = $50K	42
6) Operate12 hours/day	29
7) Combination of 3,4,6	(22)

MISER NPV at an Installation within the US



MISER Challenges

- Process efficiency
- Liquid v. gaseous fuels
- Standards for military equipment
- Cost

Conclusions

- **If MISER can produce liquid fuels from mixed waste, it likely will be cost effective in overseas military use**
- **If MISER produces only gaseous fuels, it likely will be better suited for stateside use, on military bases and elsewhere**
- **If MISER output can feed a militarily practical fuel cell, its investment attractiveness will depend on the rate at which it can transform waste and its cost**
- **Waste-to-fuel process efficiency could be improved through the use of readily convertible plastics in place of paper, fiberboard and wood packaging**